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STUDY OF BONDING METHODS

ON

"ALUMINUM BEAM LEADED" DEVICES ON MICROCIRCUIT CERAMIC SUBSTRATES

NASA CONTRACT NO.: NAS8-27865

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FINAL REPORT

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INTRODUCTION

One of the most significant developments during the past ten (10) years in the hybrid technology has been the development of the beam lead device. Both the gold beam lead (Bell Telephone Laboratories) and the aluminum beam lead (M.B.L.E., Belgium) technologies were developed at approximately the same time. The gold beam lead technology has been emphasized in the United States where the semiconductor technology was growing the fastest. However, in Europe, the widespread acceptance of beam lead devices has not yet been realized. This program has shown that the aluminum beam lead (Al BL) devices are reliable and can be utilized in hybrid circuits by modification of existing processing equipment.

This final report will summarize the results of the entire program including tables and graphs to provide sufficient detail for processing Al BL devices onto hybrids. Recommendations and conclusions will be given based on the experience and results obtained to date. Wherever applicable, principles, procedures and methods of application of Al BL devices will be discussed such that the results of this study may be utilized.

FINAL REPORT

"ALUMINUM BEAM LEADED" DEVICES

OBJECTIVE

The objective of this program was to investigate, test and evaluate the methods used for the bonding of aluminum beam lead (Al BL) devices onto hybrid microcircuit substrates used in high reliability space applications. The program was to originate standards, controls and screening techniques which would inhibit the occurrence of failures resulting from the bonding methods employed.

The bonding schedules derived from the investigation was used to bond Al BL devices onto thin film substrates. The bonded devices were processed through reliability test to qualify the bonding processes. All electrical and mechanical data, including failues were collected and analyzed to determine the reliability of the processes.

PRCGRESS

The very first step undertaken in this program was to investigate the methods required to handle the minute devices. Arrangements were made to visit M.B.L.E. of Belgium who is credited with the developing of the Al BL technology and presently the only manufacturer of the devices. During the visit, Mr. P. Grosjean and Dr. M. Baroen were extremely helpful in providing technical information required to handle the small devices. The importance of special handling equipment was discussed in great detail. The most appropriate

PROGRESS (Continued)

equipment is one that is designed to manipulate the 200 mm (8 mil.) square devices without making contact to the aluminum beams. The nonbonding side of the beams are coated with a silicon oxide which will weaken or destroy the beam if broken.

Typical dimensions of an aluminum beam are:

Length	-	80 mm (3.2 mils.)
Width	-	60 mm (2.4 mils.)
Thickness	-	6 mm (.25 mils.)

A tapered dowel pin was designed with an axial vacuum hole to pick up the device on its major back surface. This allowed the device to be picked up and placed where needed without any damage to the device or its beams. This method is very similar to the method used for handling bump flip chip devices. Once the proper handling equipment is obtained, they can be handled without any unusual difficulty. The devices had to be registered to the substrate metallization pattern within 12 mm (0.5 mil.) of their designed location (see Figure 1). This was achieved by manipulating the device holder and rotating the substrate stage.

During the M.B.L.E. visit, it was also learned that the devices had to be temporarily bonded to the substrate to prevent the device from spinning away during the ultrasonic bonding of the beams. Any one of several fluxes that has

PROGRESS (Continued)

the proper viscosity and a reasonable set-up and curling time may be used for the temporary bond. An epoxy dispensing system (Laurier Assoc. Model M101) was adapted to dispense a consistent uniform size flux droplet for the temporary bond. A pressure of six (6) psi for 4.5 seconds through a 25 mm (1 mil.) diameter hyperdermic syringe provided a 80 mm (3 mil.) diameter flux droplet. Because of the tight tolerance required in positioning the Al BL device to the etched aluminum pattern on the substrate, the flux had to be accurately positioned on the substrate between the bonding pads, see sketch in Figure 1. The size of the droplet must be very well controlled because too large a droplet will cause flux to flow under the beam and may interfere with bonding. Also, too large a droplet may cause the device to move after it is released from the pick up tool and result in a misaligned device. Since the device must be registered to the metallization pattern to 12 mm (0.5 mil.) very little movement is reason for rejection. A pneumatic control was added to the epoxy dispenser for raising and lowering the needle. This is used to lower the dispensing needle just above the substrate prior to dispensing the glue and then raising the head after applying the glue. This allows the application of the glue and placement of the Al BL device to be done within the same viewing area of the stereo microscope. It also prevents any

PROGRESS (Continued)

interference between the dispensing head and the pick up tool.

The viscosity of the flux must be fairly well controlled to deposit a consistent size droplet. Several alpa fluxes (828-10 and 828-20) had a viscosity that was too low to form a small droplet of flux. Attempts to increase the viscosity of the alpa fluxes were not successful. This was caused by the low vapor pressure of the dilutent used in the flux. A flux with a higher initial viscosity, Kester 1544, was used successfully by increasing its viscosity by heating the flux to 300°C for 15 minutes and then placing the flux in a vacuum for three (3) minutes. The modified Kester 1544 flux was successfully used to form a 75mm (3 mil.) diameter hemispherical droplet.

After a flux droplet is formed on the substrate, the device is placed on the substrate in position for ultrasonic bonding. When all the devices are added to the substrate, the flux is cured at 125°C for 15 minutes. After curing the substrate, the devices are inspected for the following:

1. Alignment of beams with metallization pattern.
2. Any flux spreading into the bond area between the beam and the metallization.
3. Any damaged devices.

Many of the above problems can be resolved at this point in the processing by individually replacing a damaged or mis-

PROGRESS (Continued)

aligned device. A more detailed discussion of the rebonding operation is given in Addendum I on Pages 26 and 27. A well controlled process will have very few of these problems after an operator is experienced.

It was also learned during the M.B.L.E. visit that more reliable devices with higher beam strengths were developed recently by forming the beams from aluminum having 1% silicon. This is analogous to the semiconductor industry using aluminum wire with 1% silicon to increase the wire strength. All isostrength and electrical devices used in the program had beams made of aluminum with 1% silicon.

Initial ultrasonic bonds were made to the aluminum beams using bonding tips of various geometries. The following geometries were experimented with:

1. 125 mm (5 mil.) round metal capillary having a 25mm (1 mil.) (Micro Swiss #15-001-15)
2. Aluminum wire wedge metal tips (MicroSwiss # 5006 and Gaiser tool - #2009-20)
3. Hemispherical metal tip having a 10 mil. diameter.
4. Hemispherical sapphire tip having a 3 mil. diameter.

The first three types of tips resulted in excess damage to the beams of the device. It appeared that the contact surface area was too large with respect to the size of the beam. When the pressure and ultrasonic energy were high enough to break through the silicon oxide on the beam, the beam would be

PROGRESS (Continued)

pinched off and be severed from the device or result in a very low tensile strength. A sapphire tip was designed with a smaller hemispherical point with a diameter of 75 mm (3 mils.). This allowed the point of the tip to break through the silicon oxide of the beam without destroying the beam. For more uniform bond strengths, the bond should be made on the outer 1/3 of the beam and centered across the beam's width as shown in Figure 2. When the bond is made too close to the edge or end of the beam, splitting may occur as shown in Figure 3. The bond area will be indicated by the fractured silicon oxide film on the beam. Additional discussion on the silicon oxide film is given in Addendum II on Page 28. If the silicon oxide is not fractured, then the bond strength is questionable and will generally be one gram or less.

The Al BL devices were bonded to aluminum films on glazed alumina substrates. The substrates were 1.8 cm square and had a pattern etched in the NiCr-Al film that accepted six bonded Al BL devices. The acceptable standard in the semiconductor industry for ultrasonic bonding is a film thickness of 12,000 angstroms. Bonding Al BL devices to films of this thickness caused holes to be punched into the beams and therefore, destroying the beams. Dr. Baroen, Production Manager for Beam Lead Devices at M.B.L.E., recommends films from 25,000 to 60,000 angstroms for consistent and reliable bonds.

PROGRESS (Continued)

Films below 25,000 angstroms gave erratic and inconsistent bonds whereas films above 60,000 angstroms made it too difficult to control pattern geometrics. The ECI thin film substrates were fabricated from films having a thickness of 30,000 angstroms.

Considerable undercutting of the aluminum conductors was noted when the ECI standard aluminum etching procedure was employed on the 30,000 angstrom films. A phosphoric acid etchant was used to reduce the undercutting but the acid generated ragged edges along the conductors. The final solution which resulted in highly resolved lines with little undercutting was accomplished by increasing the temperature of the alkaline etchant to 60 degrees centigrade and agitating the etchant. The necessary patterned substrates were sent to M.B.L.E. for their sample beam lead bonds using the BSV63 devices.

The equipment that was modified to handle and accurately position the devices onto the substrate was also modified to accept the sapphire bonding tip. This equipment was then used to make bond samples while varying the bonding parameters. The main three parameters to be varied when bonding Al BL devices are time, pressure, and energy. Initial bonding showed that applying an ultrasonic pulse for too long a period will rupture the bond. On the other hand, too short a pulse will

not produce an adequate bond. An ultrasonic pulse time of 250 milliseconds was selected for the best time setting. The bonding force required to make a bond is varied by adjusting the weight applied to the beam through the sapphire bonding tip. The weight was varied from 3 to 10 grams for the three mil bonding tip. The amount of deformation (set-down) in the aluminum beam is directly related to this bonding force. A final setting of 7.0 grams was selected for the best set-down and bond pull strength. The pull strength of the bonds also indicated that the best bond was obtained at an energy of approximately 35 milliwatts.

An isostrength diagram was used to show that the optimum settings were selected for the bond schedule. Both energy and weight were varied about the optimum settings of 32 milliwatts and 7 grams. This clearly showed that the optimum settings were correct and that variations of ± 20% in either or both variables would produce good bonds, see the bond schedule diagram in Figure 4 and the pull strength data in Table 1.

The pull strengths of the beam lead bonds were performed on a dynometer type pull tester previously used for pull testing one mil gold wire. Initially the pull tester gave erratic results which was attributed to the dynometer arm sliding over the device being tested. This was due to the radius arm on the dynometer rotating within the guage and moving away from the device. The pull tester was modified

such that the dynometer gauge was rotated about a center which was concentric with the radius axis of the rotating radius arm. Several sample bonds were pull tested and the radius arm did not move away from the sample being tested. The dynometer pull tester was used for all pull strength readings of the bonded devices.

The dynometer pull test applies a force to the Al BL device that is parallel to the substrate and between two beams bonded to the substrate. The strength of the bonds prior to the isostrength diagram was tested on the special dynometer pull tester. Here the test applied a force between two adjacent beams bonded to the substrate. The force would then be increased until the Al BL device failed mechanically. Bonds made at the optimum setting had bond strengths that averaged four grams per beam. The isostrength diagram was completed by bonding all four of the beams on 45 Al BL devices at the optimum settings. All four beams were bonded so that the pull test results of the environmental devices could be compared to the readings obtained for the isostrength devices. The pull strengths of the isostrength samples were lower because the test could not be performed in the same manner as the previous devices. When all four beams are bonded, the force is applied perpendicular to the aluminum beams. This produces a torsional force as well as shearing force, therefore, producing lower pull test readings. The average pull strength was three grams per beam with more pull

strength variations than when only two beams were pull tested, see Table 1. The reason for pull testing only two adjacent beams of a device while determining the optimum bond settings was that the pull strengths were more consistent and sensitive to changes in the bonding parameters. This allows one to obtain a bond schedule that provides the best bond that is less dependent on the method of pull testing.

After the bonding schedule was determined and verified by bonding the isostrength samples, the electrically good devices were bonded in the following manner. All of the 144 Al BL devices were temporarily attached to the substrates with a precisely controlled amount of flux. The devices were then ultrasonically bonded at a time, weight and power setting of 250 milliseconds, seven grams and 35 milliwatts respectively. When the flux was chemically desolved from the substrates, the devices were electrically tested. Only one of the devices was not functioning electrically. Visual inspection at 30X magnification indicated that the emitter beam had severed at the bond edge. The same emitter beam was rebonded and additional tests proved the device to be functioning electrically. The flatpacks were hermetically sealed by the reflow solder technique with every package having a leak rate less than 5 X 10^{-8} cc/sec. Electrical test after sealing verified that all the devices were electrically good. After the packages were marked with their proper identification number, they were placed in an oven at 125°C for the initial conditioning screen of 240 hours.

This phase of the program went very smoothly without any problems. Only one broken beam out of the nearly 600 bonds caused a failure. The broken beam was easily detected by a visual inspection and a repair was readily made. One advantage of beam lead devices is the ability to inspect the bonds, and in this particular case, it has proven itself to be an important advantage.

Testing of the modules after completion of the initial conditioning screen test showed that none of the devices had failed or changed electrical parameters appreciably. The 144 devices were then divided into the four test groups of 30 each plus the control group of 24.

Upon completion of each test, 15 of the 30 units were subjected to destructive adhesion tests. This sample was to contain any suspect or known defectives that were detected by electrical measurements after the test exposure. The balance of the sample was to be selected at random. Since no defectives were indicated, all samples were selected at random. The remaining 15 samples will be identified and provided to NASA/MSFC for evaluation.

The test groups were then exposed to the following environmental test conditions as stated in each test:

1. <u>Initial Conditioning Screen (144 Samples)</u>
   The units were given an initial electrical test and then subjected to a 240 hour conditioning bake at 125°C. On completion of the conditioning bake,

the samples were retested to verify operability.

2. Thermal Shock (30 Samples)

The samples were subjected to 25 cycles of thermal cycling in accordance with MIL-STD 883, Test Method 1010, Test Condition A, except the transfer time did not exceed 15 seconds. The temperature range was from $-55^{o}C$ to $+85^{o}C$. The condition of the samples was electrically verified after the first 15 cycles and on completion of the 25 cycle test.

3. Vibration Fatigue (30 Samples)

The samples were subjected to vibration, variable frequency in accordance with MIL-STD 883, Test Method 2007, Test Condition A. The frequency range was 20 to 2000 cycles varied logarithmically, one cycle 20-2000-20 traversed in four minutes, four cycles in each of the three orientations. Total vibration time was 48 minutes. The condition of the samples was electrically verified after each orientation.

4. Step-Stress Test (30 Samples)

The samples were subjected to a combined vibration temperature step-stress test and in the exposure sequence shown in Figure 5. The vibration procedure was the same as the vibration fatigue test except that the parts were vibrated in the vertical plane only. Vibration at each temperature shown was not begun until the parts were stabilized at that

temperature. After each test step exposure, the samples were tested electrically to determine their condition. Since no failures occurred through the last step, the units were returned to test at Step 8 and alternated between Steps 7 and 8 until failures occurred or the vibration time at each of the two steps totaled 48 minutes.

All four environmental tests were completed without any electrical or mechanical failures. The test data is attached to this report. After completion of the environmental test, the destructive adhesion test was performed on half of each sample lot. The devices in the initial adhesion group were pull tested with an average shear strength of 10 grams (Type 1). This compares favorably with the 11.9 grams average shear strength obtained from the isostrength bond samples (Type 2). The average shear strength after thermal shock had a value of 8.1 grams (Type 3), and the average shear strength after vibration fatigue was 9.1 grams (Type 4). The step-stress samples had an average shear strength of 11.5 grams (Type 5) as shown in Figure 6.

The step-stress test group had each device tested and data recorded 12 times during the test. The test data shows that the beta of the devices did not vary by more than ±2% over the entire test program. This shows the stability of the devices and their bonds.

An initial goal of the program was to try to obtain aluminum beam lead samples bonded to ECI substrates by M.B.L.E. These

M.B.L.E. samples were to be pull tested and then compare the results with those bonded by ECI. During the early phase of the program, Mr. P. Grosjean and Dr. M. Baroen of M.B.L.E. agreed to make the bond samples to the ECI substrates. The substrates with thick aluminum patterns were sent to M.B.L.E. in April of 1972. Unfortunately, the sample substrates were not received by M.B.L.E. before their production bonding project was completed. After considerable thought, Dr. Baroen recently informed ECI that it was not feasible for M.B.L.E. to do any of the sample bonding that they had hoped to do for the study program. Therefore, the M.B.L.E. samples were not available to compare with the ECI samples.

RECOMMENDATIONS AND CONCLUSION

The Al BL devices have proven to be very stable and reliable during this program. Even though the actual devices are very minute in size, they could be manipulated and handled without too much difficulty once proper equipment has been obtained. It was shown that existing standard hybrid equipment could be modified to handle the Al BL devices with high yield and good performance.

The availability of devices appears to be the major disadvantage to the Al BL technology. Presently, the only known source of devices is M.B.L.E. of Brussels, Belgium. M.B.L.E. has developed the technology and used it in production with satisfactory results.

The parts were delivered from M.B.L.E. in glass packages with individual compartments for each device. Inspection of the parts after they were received showed that less than 4% had damaged beams and all of the devices were electrically good. The devices were checked for physical damage to the beams by inspecting the silicon oxide layer on the backside of the beam for cracks at 30X magnification. The silicon oxide layer gives added rigidity and strength to the beams and therefore, will result in weakened beams when the oxide is cracked. The formation of the beams from aluminum containing 1% silicon has also improved the strength of the beams. The vendor's quality control inspection appears to have been exceptional since none of the 250 devices received had any physical shorts or opens to cause electrical failures. The overall appearance of the devices was excellent.

The films on the alumina substrates used for bonding the Al BL devices should have a thickness in the range of 25,000 to 60,000 angstroms. This is considerably thicker than the standard 12,000 angstroms used for integrated circuits, but necessary to prevent the bonding tip from punching through the beam. Films greater than 60,000 angstroms make it too difficult to delineate precision patterns required for bonding. The etched pattern must have as little undercutting as possible so that the beams on the devices can be aligned and bonded to the top surface of the film, see Figure 1. The

spacing between the bonding pads on the substrate must be from 25 to 75 mm (1 to 3 mils.) so that the devices can be properly registered to the film pattern. This spacing must include the undercutting of the aluminum film. The ECI substrates had a 30,000 angstrom aluminum film with an average spacing between bonding pads of 45 mm (1.8 mils.). These parameters were easy to maintain once they were achieved through existing processes that were modified. The previously mentioned ECI parameters presented no problems in alignment or registration between the device and the substrate pattern (see Figures 2 and 3).

The devices were stored in their original shipment packages and kept in dry nitrogen filled desiccators. Vacuum pick up tools were used to transfer the devices from the package to the bonding station. A hypodermic needle small enough to pick up the device by the silicon surface must be used to prevent damage to the beams. Care must be used to prevent bending the aluminum beams and cracking the silicon oxide layer on the beams. The devices on the bonder were transferred to the substrate by a capillary tip using vacuum pick up, again on the major silicon surface. The bonder must have some means of moving the device or substrate in the X,y direction with an angular movement. The movement controls must be fairly smooth so that the device can easily be aligned to the substrate pattern. Again it is important to prevent damage to the aluminum beams.

A modified K&S ultrasonic bonder Model 422 with a Buyfield generator, Model 201, was used for the bonding. The low power setting was used at 1.5 (35 milliwatts) for a bonding time of 2.2 (250 milliseconds) and a force of 7 grams. The Buyfield generator is the sweep frequency model tunable about 60 kilohertz. A sapphire tip having a polished 75 mm (3 mil.) hemispherical tip was used as the bonding tool. A sapphire tip is better than a metal tip because it can be polished and made smaller. The polished tip should be small enough so that the bond area on a beam is within the outer 1/3 of the beam. Wedge type tips are generally too large and cause the beam to be pinched off which results in a weaker bond.

Because of the small size of the device and the ultrasonic energy present, the devices must be temporarily bonded. This temporary, but weak bond, is necessary to prevent the device from spinning around and becoming misaligned on the substrate. A mild noncorrosive flux provides a sufficient enough bond and can easily be removed with a solvent. Kester flux type 1544 was used with very successful results in this program. Some means of controlling the flux droplet on the substrate is necessary for consistent and high quality results. An epoxy dispenser, Laurier Associates Model M101, is capable of controlling a 75 mm (3 mil.) droplet to the necessary tolerances. The size of the droplet is controlled by pressure, orifice size and time. Too small a droplet has insufficient bond strength and too large a droplet may interfere

with beam bonding or cause the device to float and become misaligned. After the flux is cured, the devices must be inspected for damaged devices, misaligned devices or excess flux in the beam bonding area. Make any corrections or replacements prior to ultrasonic bonding. When all devices are inspected and approved, the beams should be ultrasonically bonded. Remove the flux by rinsing in a solvent such as Dow-Clean DWR solvent or equivalent. The devices should be inspected for:

1. Damaged beams or devices.
2. Incomplete bonds (silicon oxide not penetrated).
3. Misaligned devices.
4. Flux residue.

Many of the repairs can be readily made by rebonding an incomplete bond or replacing a damaged or misaligned device.

When an operator becomes proficient in handling and bonding the Al BL devices, it is possible to get a very high yield. The program consisted of nearly 1000 ultrasonic beams being bonded to the isostrength schedule with less than 0.2% bond failures.

All of the 144 environmental samples have completed their respective environmental test without any failures, mechanically and electrically. This shows the reliability and stability of both the processes and the devices. When all of the devices completed the Visual and Conditioning Screen tests, they were divided into sample lots of 30 each. At the

completion of each environmental test, Thermal Shock, Vibration Fatigue and Step Stress Test, half of the devices were tested for bond pull strength. The pull strengths values were generally less than the isostrength values but were within ±20% of the average. The fact that no mechanical or electrical failures occurred indicates that the technology is reliable and the processes can be well controlled.

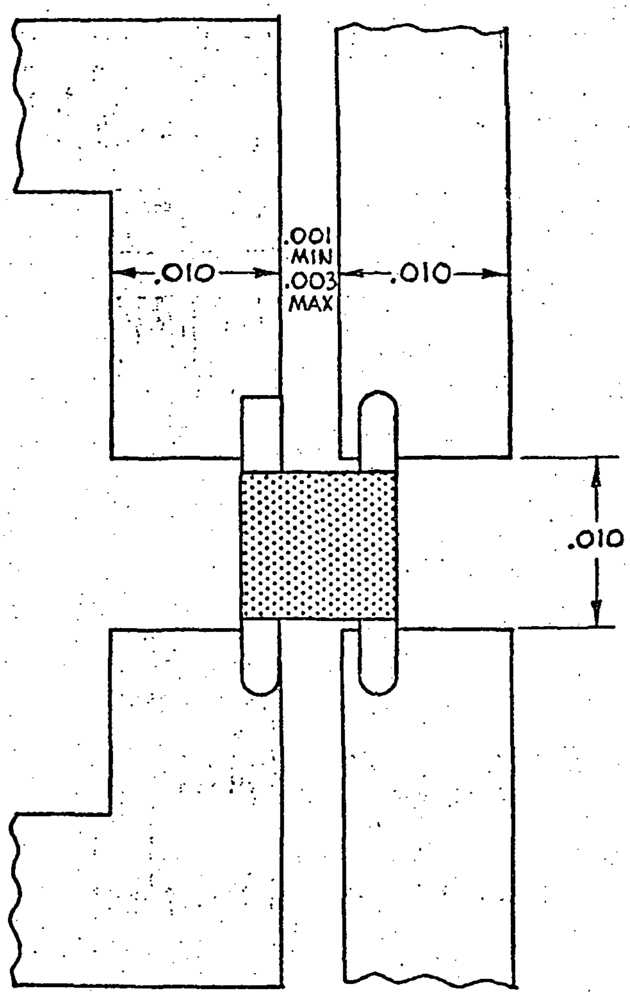


FIGURE 1 - BONDED BEAM LEAD DEVICE

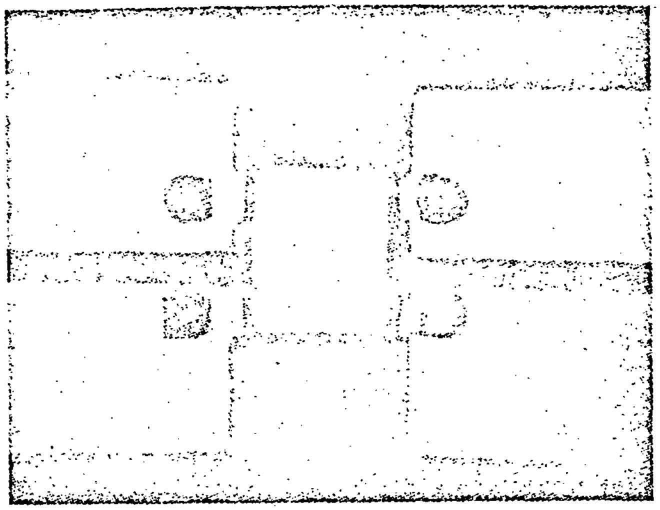


FIGURE 2 - IDEALLY BONDED DEVICE

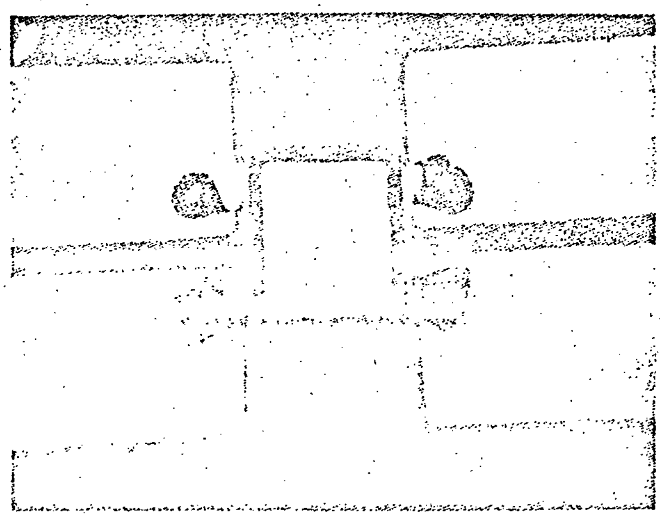


FIGURE 3 - BEAM SPLITTING AT BONDS

Company Electronic Communications, Inc.
Department 240 Microelectronics Lab

Technician Lori Bileni
Inspector
Welding Supv.

WELD POWER SUPPLY
Manufacturer Raytheon
Model No. 201
Serial No. 3471
Type of Bond

WELD HEAD
Manufacturer KFS
Model No. 422
Serial No. 317
Bond Station No. 11

PREDOMINANT FAILURE
CW (Center Wire)
FA (Film Adhesion)
CB (Complete Bond)
BE (Bond Edge)
BF (Bulk Film)
S (Substrate)
BW (Bulk Wire)

Aluminum Beam Lead - MBLE - Devices

ELECTRODES OR CAPILLARY (UPPER)
Material
Tip Size ______ Radius
Tip No. ______ Polarity
P.O. ______ Included Angle
Vendor

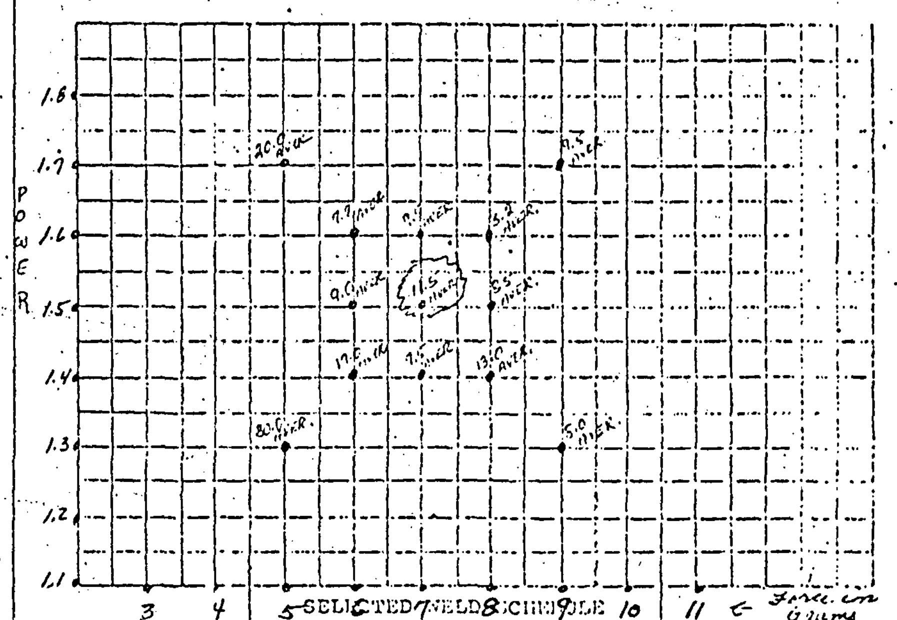
SUBSTRATE
Material Alum. Mic. Strip
No. ______ P.O.
Vendor E.C.I.

WIRE (UPPER)
Material ______ Size
Tens. Str. ______ Melt#
P.O. ______ Vendor

WIRE (LOWER)
Material ______ Size
Tens. Str. ______ Melt#
P.O. ______ Vendor

ELECTRODES (LOWER)
Material ______ Tip Size .003R
Polarity ______ Included Angle
Tip No. ______ P.O. 20237279
Vendor

CLEANING PROCEDURE



Time	Power	Force
2.2	1.5	78

ISO-STRENGTH DIAGRAM NO.

DATE: Aug. 29, 1973

FIGURE 4 - BOND SCHEDULE DIAGRAM

TABLE 1 - ISOSTRENGTH PULL STRENGTHS

Aluminum Beam Lead [illegible] QUALIFICATION FORM
MBLE [illegible]

[illegible]	HEAD	ISO-STRENGTH DIAGRAM
Mfr. Bayfield	Mfr. K&S	No. ______
Model 201	Model 422	BOND STATION # ______
Ser. No. 9491	Ser. No. 347	

MATERIALS	ELECTRODES
Upper ______	Upper ____ Tip Size ______ Polarity ______
Tensil Str. ______	Lower ____ Tip Size ______ Polarity ______
Lower alum-Subs.	Other Brown Diamond Inc.
Tensil Str. ______	Sapphire tips

i	Fracture Strength Area	X_i	$\bar{X}$	$(X_i-\bar{X})$	$(X_i-\bar{X})^2$	i	Fracture Strength Area	X_i	$\bar{X}$	$(X_i-\bar{X})$	$(X_i-\bar{X})^2$
1		12 gr.	11.9	.1	.01	26		13 gr.	11.9	1.1	1.21
2		16 gr.		4.1	16.81	27		15 gr.		3.1	9.61
3		9 gr.		2.9	8.41	28		5 gr.		6.9	47.61
4		14 gr.		2.1	[illegible]	29		20 gr.		8.1	65.61
5		9 gr.		2.9	8.41	30		22 gr.		10.1	102.01
6		5 gr.		6.9	47.61	31		12 gr.		.1	.01
7		9 gr.		2.9	8.41	32		9.5 gr.		2.4	5.76
8		11 gr.		.9	.81	33		11 gr.		.9	.81
9		12 gr.		.1	.01	34		21 gr.		9.1	82.81
10		10 gr.		1.9	3.61	35		6 gr.		5.9	34.81
11		15 gr.		3.1	9.61	36		5 gr.		6.9	47.61
12		14 gr.		2.1	4.41	37		9 gr.		2.9	8.41
13		12 gr.		.1	.01	38		14 gr.		2.1	4.41
14		7 gr.		4.9	24.01	39		15 gr.		3.1	9.61
15		7 gr.		4.9	24.01	40		10 gr.		1.9	3.61
16		9 gr.		2.9	8.41	41		14 gr.		2.1	4.41
17		4 gr.		7.9	62.41	42		15 gr.		3.1	9.61
18		7 gr.		4.9	24.01	43		7 gr.		4.9	24.01
19		14 gr.		2.1	[illegible]	44		12 gr.		[illegible]	[illegible]
20		14 gr.		2.1	[illegible]	45		9 gr.		2.9	8.41
21		15 gr.		3.1	9.61		Σ	535.3		Σ	928.68
22		20 gr.		[illegible]	65.61			11.9			20.63
23		21 gr.		[illegible]	[illegible]						
24		7 gr.		4.9	[illegible]						
25		16 gr.		4.1	[illegible]						

$\sigma = \sqrt{\frac{1}{n}\sum(x_i-\bar{X})^2}$

Average Weld Strength ($\bar{X}$) 11.9

Standard Deviation (σ) 4.5

$0.10\ \bar{X}$ = 1.19

Technician Lore Bieler

Inspector ______

Welding ______

Date Jan. 29-1973

Not Accept [illegible]

NOTE: [illegible] of the [illegible] wire, or 75 [illegible] minimum on .002" - .010" [illegible]

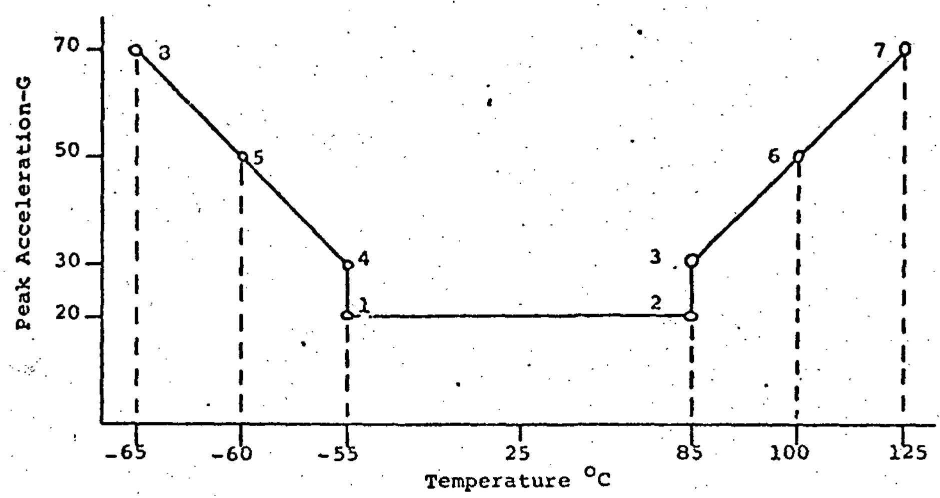


FIGURE 5 - STEP STRESS TEST

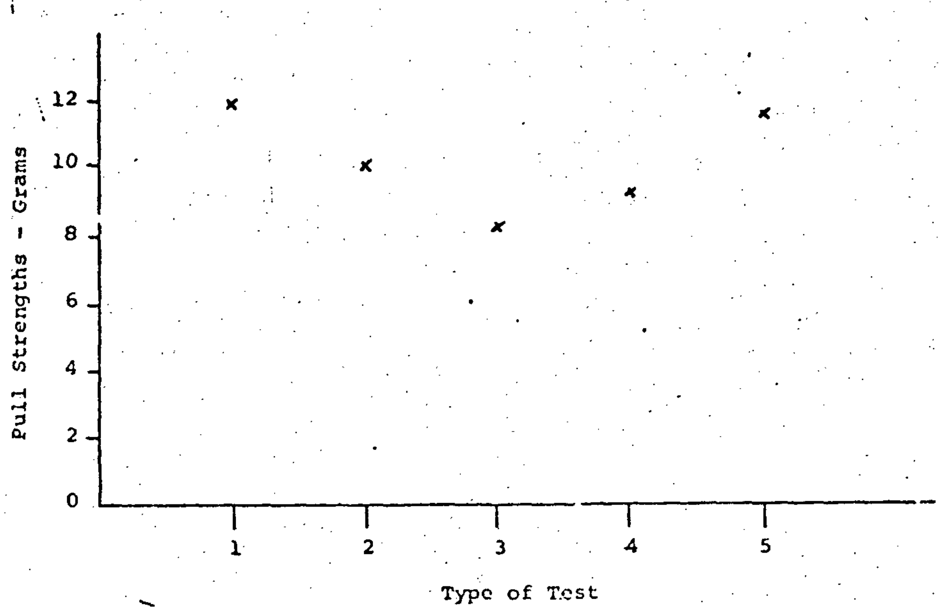


FIGURE 6 - AVERAGE PULL STRENGTH vs.
ENVIRONMENTAL TEST

ADDENDUM I - REBONDING OPERATION

One of the most important advantages of beam lead devices is the ability to inspect the bonds after the devices are assembled to the substrates. When defective bonds are found, it must be determined what must be done to correct the defects. The type of action that should be taken depends on what type of defect has occurred in the bond. The type of repair that can be accomplished falls into one of two catagories:

1. Rebond the same device.
2. Remove the bonded device and replace it with a new device.

A case where a device can be rebonded may be where a beam was missed during initial bonding, or where a beam was bonded too close to the end of the beam and the beam was pinched off around the bond, or an incomplete bond was made. Incomplete bonds were made during the initial phase of the program when low energy settings were used on the ultrasonic power supply to determine the optimum isostrength parameters. These incomplete bonds could be salvaged by rebonding the beams using the optimized bonding parameters to achieve a good bond. It has been concluded that an incomplete bond can be corrected by rebonding the beam in the same bond area if that area has not been severely damaged. At the other extreme of the bonding parameters where energy or pressure settings are too high, there is a tendency to blow a hole through the beam and/or the aluminum film on the substrate.

This type of defective bond requires a new device to be bonded in a new bond area that has not been damaged. When a device is removed, the complete beam/beams must be removed prior to placement of a new device. This is done to maintain a planar bonding surface so that a beam on the new device would not become fractured and defective.

ADDENDUM II - SILICON OXIDE FILM

Whenever the ultrasonic tip penetrates the silicon oxide on the back of the aluminum beam, the aluminum becomes deformed. This deformation and the high adhesion between the aluminum beam and the silicon oxide allows the cracked silicon oxide to remain attached to the beam.

REPORT SUMMARY SHEET

1. COMPONENT PART NAME PER GENERIC CODE: Aluminum Beam Lead Transistors	2. PROGRAM OR WEAPON SYSTEM: General Use
4. ORIGINATOR'S REPORT TITLE: Bonding Method Study of AL Beam Lead Devices on Ceramic Substrate	5. ORIGINATOR'S REPORT NO.: 1-2373
	6. TEST TYPE, ETC.: Evaluation

3.	DAY	MO	YR
TEST COMPL	30	3	73
REPT. COMPL	30	6	73

7. THIS TEST (SUPERSEDES) (SUPPLEMENTS) REPORT NO:

8 ITEM	8A. PART TYPE, SIZE, RATING, LOT, ETC.	9. VENDOR	10. VENDOR PART NO.	11. IND./GOV. STD. NO	12. TOTAL TESTED
1	Aluminum Beam Lead NPN Transistor, Type 2N2369	MBLE	BSV 63		144
2					
3					
4					(OVER)

13. INTERNAL SPECS ETC REQ'D TO UTILIZE REPT.	ENCL	SENT WITH REPORT NO.	14. MIL. SPECS./STDS. REFERENCED IN 15C
A Step Stress Test Plan	X		D Mil-STD-883
B			E
C			F

15A 8 ITEM	TEST OR ENVIRONMENT	C PER SPEC	D SPEC. PARAGRAPH/ METHOD/CONDITION	E TEST LEVELS, DURATION AND OTHER DETAILS	F NO. TESTED	G NO. FAILED
1	Initial Conditioning			240 Hr. Bake at 125°C. Unpowered	144	0
1	Thermal Shock	D	Method 1010	Test Condition A	30	0
1	Vibration Fatigue	D	Method 2007	Test Condition A	30	0
1	Step Stress Test			See Attached	30	0
						(OVER)

16 SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN:

Test to evaluate the bonding method proposed for use on High-rel Hybrids 4 circuits. Twenty-four of the units prepared for the test were held as control samples. The results of the test show that the procedure used was satisfactory.

(OVER)

21 REPT NO

17 TESTED BEYOND VENDOR CATALOG SPECIFICATIONS YES | 18. VENDOR INFORMED OF TEST RESULT BY LETTER / COPY OF REPT / ORAL | 19. SIGNED | 20. CONTRACTOR | SUBCONTRACTOR

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, of conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

TABLE OF CONTENTS

SPE-15A

1.0 Reason for Test: To evaluate microelectronic bonding techniques and processes for bonding Aluminum Beam Lead Devices.

2.0 Description of Test Samples (2N2369)

The Aluminum Beam Lead Devices were NPN transistors purchased from MBLE of Brussels, Belgium. There were a total of 144 devices bonded to 24 alumina ceramic substrates that were hermetically sealed in flatpacks.

3.0 Disposition of Parts: All parts were returned to the Project Engineer in Microelectronics Laboratory.

4.0 Abstract, Conclusions, Recommendations

4.1 Abstract: This report describes the effects of thermal shock, sine vibration (vibration fatigue), and temperature/vibration step stress tests on beam lead chip mounting methods. Since the objective is to evaluate mounting techniques and processes rather than piece parts, a "failure" was defined as an electrical open circuit or a major change in the electrical Beta parameter.

The initial electrical Beta readings were taken to give a base for comparison of data on future tests.

There were no failures or major shifts in Beta in any of the devices after any one of the environmental tests.

4.2 Conclusions and Recommendations: See the "Summary and Conclusion" Section of the Final Report "Study of Bonding Methods on Aluminum Beam Leaded Devices on Microcircuit Ceramic Substrates" of which this section is a part.

SPE-154

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Pre Seal
PART NO. X 380 A
MFR. NAME
PART NAME Al. Beam Lead

DATE 2-21-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device number 1	2	3	4	5	6
1	49	86	88	71	85	85
2	96	63	104	46	92	58
3	100	71	71	61	71	100
4	108	94	87	90	60	98
5	104	104	80	104	54	84
6	106	85	96	98	85	70
7	71	85	92	62	68	87
8	78	85	62	96	90	92
9	45	54	75	108	87	60
10	87	85	98	80	50	102
11	59	106	67	70	94	100
12	71	80	100	96	61	[illegible]
13	67	88	112	49	77	100
14	60	67	110	85	67	71
15	85	106	49	70	94	72
16	96	60	94	86	82	54
17	90	88	85	96	100	104
18	90	87	96	94	98	61
19	80	80	100	74	90	82
20	110	100	102	93	55	96
21	80	90	71	62	54	108
22	53	52	85	62	80	74
23	96	102	90	90	46	77
24	81	90	90	100	90	80

Test Performed on Tektronix Curve Tracer Type 575 S/N-10815R.
Approx. Beta Parameters used for Calculations:
$V_{CE} = 1V$
$I_C = 1mA$

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Post Seal / Pre-Bake
PART NO. X - 380 A
MFR. NAME
PART NAME Al. Beam lead

DATE 2-23-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device number 1	2	3	4	5	6	
1	49	90	92	71	90	90	
2	96	70	108	45	92	58	
3	102	78	74	62	77	102	
4	112	98	88	93	60	100	
5	104	104	82	106	54	71	
6	110	86	98	100	86	71	
7	74	85	96	65	70	90	
8	80	83	62	98	90	96	
9	45	55	77	110	88	60	
10	88	85	102	81	50	104	
11	58	106	66	70	92	100	
12	75	80	104	98	83	58	
13	66	88	112	48	78	104	
14	62	62	110	85	70	72	
15	83	106	49	70	96	77	
16	98	60	94	90	85	54	
17	92	90	88	96	104	108	
18	90	90	96	92	100	62	
19	80	82	106	80	90	84	
20	[illegible]	102	104	94	60	96	
21	80	92	71	62	60	110	
22	56	50	83	62	80	77	
23	100	108	96	92	46	76	
24	85	90	90	100	93	80	

SPE 257

REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Post Bake
PART NO. X-3EC A
MFR. NAME
PART NAME Al - Beam lead

DATE 3-6-73
TESTED BY H Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device Number					
	1	2	3	4	5	6
1	48	86	90	70	100	85
2	98	68	112	47	94	56
3	92	82	76	60	70	90
4	102	90	83	80	56	104
5	106	114	85	110	70	70
6	116	90	98	106	88	96
7	70	83	94	65	67	87
8	83	94	67	102	94	102
9	42	52	68	90	90	60
10	96	94	140	90	55	120
11	59	102	70	70	90	118
12	90	88	118	125	90	67
13	42	83	148	47	74	100
14	63	66	114	90	47	80
15	114	138	57	74	118	87
16	87	57	85	83	80	53
17	76	85	73	98	90	96
18	83	85	92	85	92	60
19	80	83	102	83	88	90
20	116	100	102	94	57	96
21	82	88	68	62	52	92
22	54	50	80	59	80	73
23	100	100	96	85	45	73
24	60	104	98	92	70	80

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED After 15 Cycles c/ Thermal Shock
DATE 3-7-73
PART NO. X38CA
TESTED BY H. Crawford
MFR. NAME
WITNESSED BY
PART NAME Al Beam Lead
APPROVED BY

Flat-Pack Number	Device number 1	2	3	4	5	6
2	94	67	108	46	94	54
4	98	90	82	78	55	98
7	68	82	92	62	65	85
15	112	132	51	73	116	87
18	82	82	93	82	90	60

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED After 25 cycles of Thermal Shock DATE 3-9-73
PART NO. X 380 A TESTED BY H. Crawford
MFR. NAME WITNESSED BY
PART NAME Al. Beam lead APPROVED BY

Flat-Pack number	Device Number							
	1	2	3	4	5	6		
2	98	67	112	48	94	57		
4	100	90	83	86	57	104		
7	70	83	94	84	68	88		
15	114	140	54	76	118	90		
18	83	83	94	85	90	60		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

(Vert. Plane)

TEST PERFORMED Vibration fatigue
PART NO. X380A
MFR. NAME
PART NAME Al. Beam lead

DATE 3-9-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat - Pack Number	Device Number 1	2	3	4	5	6		
1	48	86	90	68	100	85		
5	108	114	83	110	70	77		
9	44	52	68	90	86	60		
21	80	88	67	63	53	93		
22	55	52	78	59	81	74		

SPE 257

REV. A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Vibration fatigue (Horiz. Mo-I) DATE 3-13-73
PART NO. X 380 A TESTED BY H Crawford
MFR. NAME ______ WITNESSED BY ______
PART NAME Al Beam lead APPROVED BY ______

Flat-Pack number	Device number 1	2	3	4	5	6		
1	48	83	88	70	100	83		
5	108	114	83	108	70	80		
9	46	52	67	96	88	66		
21	82	88	67	43	52	95		
22	54	51	81	59	82	73		

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED (Horiz. Minor) Vibration Fatigue
DATE 3-14-73
PART NO.
TESTED BY H. Crawford
MFR. NAME
WITNESSED BY
PART NAME Al. Beam lead
APPROVED BY

Flat-Pack Number	Device number					
	1	2	3	4	5	6
1	46	82	87	69	98	82
5	106	112	85	108	69	81
9	46	51	66	90	90	60
21	82	88	67	60	52	92
22	55	52	78	59	82	74

SPE 257

REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #1 DATE 3-15-73
PART NO. X380 A TESTED BY H. Crawford
MFR. NAME WITNESSED BY
PART NAME Al Beam lead APPROVED BY

Flat-Pack Number	Device number							
	1	2	3	4	5	6		
8	82	92	68	100	97	102		
13	64	83	48	50	76	100		
16	88	56	85	82	78	56		
19	85	85	106	86	90	91		
23	104	104	94	83	45	71		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #2 DATE 3-16-73
PART NO. X380A TESTED BY H. Crawford
MFR. NAME ______ WITNESSED BY ______
PART NAME Al. Beam lead APPROVED BY ______

Flat-Pack Number	Device number							
	1	2	3	4	5	6		
8	82	92	66	100	94	104		
13	65	83	137	49	76	98		
16	86	55	85	83	78	52		
19	82	83	104	85	90	90		
23	106	104	94	83	47	74		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #3 DATE 3-23-73
PART NO. X3ECA TESTED BY H. Crawford
MFR. NAME WITNESSED BY
PART NAME Al. Beam Lead APPROVED BY

Flat-Pack Number	Device Number 1	2	3	4	5	6		
8	82	92	67	102	97	102		
13	64	82	137	49	76	98		
16	88	55	85	83	80	53		
19	82	83	102	85	88	90		
23	104	104	92	85	44	73		

SPE 257

REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.

St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #4
PART NO. X380 A
MFR. NAME
PART NAME Al. Beam lead

DATE 3-26-73
TESTED BY H Crawford
WITNESSED BY
APPROVED BY

Flat-Pack number	Device Number 1	2	3	4	5	6		
8	83	94	67	102	94	104		
13	65	83	145	47	76	100		
16	85	54	84	83	80	53		
19	82	83	104	87	88	90		
23	106	104	92	85	46	74		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #5 DATE 3-26-73
PART NO. X38C17 TESTED BY H. Crawford
MFR. NAME WITNESSED BY
PART NAME Al Beam lead APPROVED BY

Flat-Pack Number	Device number 1	2	3	4	5	6		
8	85	96	67	104	96	104		
13	65	83	147	50	76	102		
16	88	55	85	83	80	54		
19	82	83	102	87	90	90		
23	104	104	92	85	46	73		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #6 DATE 3-27-73
PART NO. X380 A TESTED BY H. Crawford
MFR. NAME WITNESSED BY
PART NAME Al. Beam lead APPROVED BY

Flat-Pack Number	Device number							
	1	2	3	4	5	6		
8	83	96	67	102	96	104		
13	66	83	147	50	76	100		
16	87	58	85	85	80	53		
19	82	83	104	85	88	90		
23	102	102	90	85	45	92		

SPE 257

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TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #7
PART NO. X 3[illegible] A
MFR. NAME
PART NAME Al. Beam lead

DATE 3-27-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device number						
	1	2	3	4	5	6	
8	83	94	67	102	96	102	
13	66	83	147	50	76	100	
16	88	55	86	85	80	54	
19	85	85	106	87	90	92	
23	102	102	92	83	44	73	

SPE 257

REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #9
PART NO. X 380 A
MFR. NAME
PART NAME Al. Beam lead

DATE 3-28-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device number 1	2	3	4	5	6
8	82	92	86	102	94	102
13	63	82	147	49	74	100
16	85	33	85	83	77	52
19	82	83	102	85	88	90
23	102	100	91	82	46	73

SPE 257

REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #8A
PART NO. X3600A
MFR. NAME
PART NAME Al. Beam lead

DATE 3-28-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat-Pack number	Device number							
	1	2	3	4	5	6		
8	82	92	66	100	94	102		
13	61	83	147	48	74	100		
16	85	55	85	82	80	53		
19	82	83	101	85	90	90		
23	100	100	90	83	46	73		

SPE 257

REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #7A
PART NO. X380 H
MFR. NAME
PART NAME Al. Beam lead

DATE 3-29-73
TESTED BY H Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device Number							
	1	2	3	4	5	6		
8	82	94	67	102	94	104		
13	64	82	147	49	74	104		
16	87	55	87	85	78	55		
19	85	85	106	87	90	92		
23	104	104	92	85	46	74		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #3 DATE 3-29-73
PART NO. X380 A TESTED BY H. Crawford
MFR. NAME WITNESSED BY
PART NAME Al. Beam Lead APPROVED BY

Flat-Pack Number	Device Number						
	1	2	3	4	5	6	
8	82	92	67	102	91	102	
13	65	82	147	49	74	100	
16	86	55	85	85	78	54	
19	82	83	104	85	90	92	
23	104	104	94	85	76	74	

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED Step Stress #7B
PART NO. X 380 A
MFR. NAME
PART NAME Al. Beam lead

DATE 3-30-73
TESTED BY H. Crawford
WITNESSED BY
APPROVED BY

Flat-Pack Number	Device number 1	2	3	4	5	6		
8	82	94	67	102	94	104		
13	66	83	147	49	76	100		
16	87	55	87	85	78	53		
19	82	82	104	85	88	90		
23	104	102	92	83	46	73		

SPE 257
REV A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
St. Petersburg, Florida 33733

TEST PERFORMED , Average of Step Stress #1 thru #7B
DATE 3-30-73
PART NO.
TESTED BY H. Crawford
MFR. NAME
WITNESSED BY
PART NAME
APPROVED BY

Flat-Pack number	Device number 1	2	3	4	5	6	Step Stress number	
8	82	92	68	100	94	102		#1
"	82	92	66	102	94	104		#2
"	82	92	67	102	94	102		#3
"	83	94	67	102	94	104		#4
"	85	96	67	104	96	104		#5
"	83	96	67	102	96	104		#6
"	83	94	67	102	96	102		#7
"	82	92	66	102	94	102		#8
"	82	92	66	100	94	102		#8A
"	82	94	67	102	94	104		#7A
"	82	92	67	102	94	102		#8B
"	82	94	67	102	94	104		#7B
Total	990	1130	802	1220	1134	1236		
Ave.	82.5	94.16	66.83	101.67	94.5	103.0		